Chapter 1.4

Geographic Object-Based Image Analysis (GEOBIA): A new name for a new discipline

G. J. Hay, G. Castilla

Department of Geography, University of Calgary, 2500 University Dr. NW, Calgary, AB T2N 1N4. Contact email gjhay@ucalgary.ca

"If you do not know where you are going, any road will take you there."

Sterling Holloway (1905 - 1992)

ABSTRACT: What is Geographic Object-Based Image Analysis (GEOBIA)? To answer this we provide a formal definition of GEOBIA, present a brief account of its coining, and propose a key objective for this new discipline. We then, conduct a SWOT[1] analysis of its potential, and discuss its main tenets and plausible future. Much still remains to be accomplished.

1 Introduction

Like the 'famous' singer whom after 20 years of hard work - 'overnight' - becomes an international success, a relatively recent *paradigm*[2] *shift* in remote sensing image analysis has been stealthy taking place over the last two decades that promises to change the way we think about, analyze and use remote sensing imagery. With it we will have moved from more than

[1] Strengths, Weaknesses, Opportunities and Threats (SWOT)

[2] *Paradigm* refers to the generally accepted perspective of a particular discipline at a given time.

20 years of a predominantly pixel-spectra based model[3] to a dynamic multiscale object-based contextual model that attempts to emulate the way humans interpret images. However, along this new path from pixels, to objects, to intelligence and the consolidation of this new paradigm, there are numerous challenges still to be addressed. We suggest - using the terminology of Thomas Kuhn (1962) - that this *shift* corresponds to a scientific *revolution (in this context it is more appropriately – an evolution)*, that is due to a change in the basic assumptions within the ruling theory, resulting in new ideas becoming prevalent. We observe this state now, as this new technological and user driven evolution in remote sensing image analysis moves from pixels to objects and the necessary infrastructure required to generate and exploit them. To hasten a consolidation of this new paradigm, an *ontology*[4] needs to be created with a common language and understanding. By building upon previous work (Hay and Castilla, 2006), we formally propose *Geographic Object-Based Image Analysis* (GEOBIA - pronounced *ge-o-be-uh*) as the name of this new paradigm. We further propose that a worldwide GEOBIA community needs to be fostered so as to rapidly facilitate the scrutiny and dissemination of new and evolving related principles, methods, tools and opportunities.

The proceeding sections provide a GEOBIA definition and a brief account of the coining of this term, along with a recommendation for a key discipline objective. This is followed by a SWOT[5] analysis of GEOBIA's potential, and a discussion regarding its main tenets and plausible future. We note that this is but a start towards developing GEOBIA as a robust international community of practice which like the UKGEOforum[6] and newly initiated NAGeoForum[7] we envision as being vendor and software neutral. Much remains to be done.

[3] Here the term *model* refers to the principles, methods and tools behind traditional (i.e., prior to object-based) digital remote sensing image analysis.

[4] Here we draw upon the definition of (computer science) *ontology* which represents a rigorous and exhaustive organization of some knowledge domain that is usually hierarchical and contains all the relevant entities and their relations.

[5] Strengths, Weaknesses, Opportunities and Threats (SWOT)

[6] http://www.ukgeoforum.org.uk/

[7] North American GeoForum – 1st Meeting Sept, 2007. This is not a policy and advocacy group, but rather a structure to increase awareness, share information, improve communication and promote all that is geospatial without getting involved in national/state policies or legislation (*per.com* M.Madden, 2007 President Elect of the ASPRS).

2 What is GEOBIA? A definition

In simple terms, GEOBIA is object-based analysis of Earth remote sensing imagery. More specifically,

> *Geographic Object-Based Image Analysis* (GEOBIA) is a sub-discipline of *Geographic Information Science (GIScience)* devoted to developing automated methods to partition remote sensing imagery into meaningful image-objects, and assessing their characteristics through spatial, spectral and temporal scales, so as to generate new geographic information in GIS-ready format.

Here, GIScience refers to the science behind Geographic Information technology[8]. Since GEOBIA relies on RS (remote sensing) data, and generates GIS (Geographic Information Systems**)** ready output, it represents a critical bridge[9] between the (often disparate) raster domain of RS, and the (predominantly) vector domain of GIS. The 'bridge' linking both sides of these domains is the generation of *polygons* (i.e., *classified image-objects*) representing geographic objects. See Castilla and Hay (this book) for a detailed account of *geo-objects* and *image-objects*.

At its most fundamental level, GEOBIA requires image segmentation, attribution, classification and the ability to query and link individual objects in space and time. In order to achieve this, GEOBIA incorporates knowledge and methods from a vast array of disciplines involved in the generation and use of geographic information (GI). Indeed, it is this unique emphasis and dependency on RS and GI – and the challenges that accompany them[10] - that distinguishes GEOBIA from *object-based image analysis* (OBIA) as used in related disciplines such as Computer Vision and Biomedical Imaging, where outstanding research exists that may significantly contribute to GEOBIA.

---

[8] GIScience - http://www.ncgia.ucsb.edu/giscc/units/u002/

[9] A good example is the recent news that Definiens – the developer of the first commercial object-oriented image analysis software for remote sensing imagery (circa 2002) – has joined with ESRI – the undisputed leader in GIS software – to developed its Definiens Extension for ArcGIS, to better integrate both GIS and RS data and information (Definiens, 2007).

[10] This is due (in part) to the inherent complexity of RS imagery resulting from differences in sensor platforms, geometry, and resolution along with a host of physical based characteristics ranging from shadow, and atmosphere to target and look-angle variability, among others.

3 Why GEOBIA instead of OBIA?

Now that a new name and definition have been proposed, where and why did they originate? During July 4-5, 2006 the first international OBIA conference was held at the University of Salzburg, Austria. In total, 175 authors contributed to the conference from 24 different countries (Blaschke and Lang, 2006). As an active researcher in this topic, Dr G.J.Hay was invited as a guest speaker. While preparing his topic, he realized that there were numerous important unanswered questions that needed to be addressed. For example:

- In 2006, if you *Googled* the word OBIA, your top three matches would be: (1) *Offshore Biologically Important Area (2) Ontario Brain Injury Association and (3) Oregon Building Industry Association*. What then is OBIA? Do we have a formal definition, a set of objectives, an ontology to follow, a road map to the future?
- Why is OBIA? Object-based image research has been going on for several decades in labs throughout the world, but why now do we have the first international conference? What are the drivers behind this?
- Is there an OBIA community? If so who are we, where are we, what are we working on, how are we related to other communities, and how can we collaborate and build upon the strengths and experience of others?

In an effort to raise these concerns and to provide answers to these and other questions, Hay and Castilla (2006) presented a formal definition of OBIA and conducted a SWOT Analysis. They also committed to create a Wiki to facilitate further international discussion and development. A Wiki is a kind of 'open' website that allows users to add, remove, or edit all content very quickly and easily (Wikipedia, 2007). Within five days of the conference concluding (July 12, 2007) an OBIA Wiki[11] was created and 'open for business'. Since this time, there have been more than 6000 views of this page.

During several months of early interactive wiki discussions, a key concern was expressed. Specifically, the problem was that the term OBIA encompassed techniques used in many different disciplines, i.e., Biomedical Imaging, Astronomy, Microscopy, Computer Vision and others, yet *our* main interest – the majority of conference participants - focused on Remote Sensing and Geographic Information Systems. On July 18, 2006 in the OBIA Wiki Discussion section a user (Prashanth) suggested that by

[11] http://wiki.ucalgary.ca/page/OBIA (last accessed September 03, 2007)

separating the application specific components of OBIA into RS/GIS, we could create our *own* identity. He then proposed GOBIA (Geo-Object-Based Image Analysis) as the name for this new field. A number of alternative names were also suggested by others, including *OARS* (Object-based Analysis of Remote Sensing images), *GIOA* (Geographic Image-Object Analysis) and *OBARSI* (Object-Based Analysis of Remotely Sensed Imagery). After debating these and other names, on Oct 27, 2006 G.J.Hay posted to the wiki the name GEOBIA as an acronym for *this discipline*, as it builds upon OBIA roots (see Lang and Blaschke, 2006 for a brief history), while also placing – with the *GEO* pseudo prefix- an emphasis on the Geographic components this community is involved in. The more Hay and Castilla considered this name and discussed it with colleagues, the more they became convinced that it was an appropriate title for this community's identity, even if – like the other proposed acronyms - it already had an alternative meaning[12].

Hay and Castilla's argument for this new name was relatively straight forward: If the name of a discipline is intended to identify a specific community and define what they do, GEOBIA does this for our community, whereas OBIA does not. Specifically, it is unreasonable to claim the generic OBIA name only for RS/GIS applications, since there are many other communities of practice with very different objectives, data and application domains that use these techniques. To facilitate this discrimination, the term 'geographic' has been adopted as a qualifier, because it simply and elegantly distinguishes RS/GIS OBIA from these different areas. Furthermore, as a sub-discipline of GIScience (Hay and Castilla, 2006), this area of research and application requires its own unique name. Thus, based on these arguments, the acronym *GEOBIA* was selected as the heir to the successful OBIA '06 international conference: *GEOBIA, 2008 – Pixels, Objects, Intelligence. GEOgraphic Object-Based Image Analysis for the 21st Century*[13].

4 GEOBIA: A key objective

Though much of the current OBIA literature describes the use of new and or improved segmentation algorithms (see other chapters in this book), we suggest that the primary objective of GEOBIA is not that of tool building,

[12] *Geobia* is a genus of predator land planarians. The other proposed acronyms also had existing meanings, e.g., *Gobia* is a city in Ivory Coast, *oars* are used to propel a water craft and *obarsi* means 'origin' in Romanian.

[13] http://www.ucalgary.ca/GEOBIA/

but rather the generation of geographic information (from remote sensing imagery), from which intelligence can be obtained. Here, *intelligence* refers to geographic information that enables users to effectively perceive, interpret and respond to some specific issue[14], such as global climate change, natural resource management, Landuse/Landcover mapping, and others.

Building on these ideas, we propose that the primary objective of GEOBIA as a discipline is to develop theory, methods and tools sufficient to replicate (and/or exceed experienced) human interpretation of RS images in automated/semi-automated ways. This will result in more accurate and repeatable information, less subjectivity, and reduced labor and time costs. In return, we envision that new opportunities will be developed within emerging GI markets. For example, Wade Roush (2007) describes how *virtual* and *mirror worlds* (such as *Second Life* and *Google Earth*, respectively) will merge into what is being called the *Metaverse*, which will look like the real earth and will ….[function] as the agora, laboratory, and gateway for almost every type of information-based pursuit. In order to perform multiscale analysis and queries of geographical features and places – which are part of the fabric of this Metaverse - GEOBIA will certainly find its way here as it delineates and partitions RS images of the planet based on predefined criteria. This will be especially relevant for generating (new) temporally sensitive geographic information/intelligence. Essentially, GEOBIA provides a way to move from simply collecting images of our planet, to creating geo-intelligence[15] (as defined above).

5 Why is GEOBIA?

Now that a definition and key objective have been proposed, let's step back and examine possible reasons for its emergence? Hindsight reveals that GEOBIA exists in response to a series of drivers that have appeared over the last two decades. These include, but are not limited to:

- A change in US space policy in the early 1990's and more recently (2003) with an emphasis on fostering commercial remote sensing policy (Hitchings, 2003). This has lead to a dramatic increase in commercially available high-spatial resolution remote sensing imagery

[14] That is, '…geoinformation within a specific user context.'

[15] We note that as defined here, this concept is not explicitly related to *geointelligence* as specified for security purposes, though it can be used as such.

(< 5.0 m) and the need to develop new value-added markets from these multi-billion dollar investments.
- The daily generation of Terabytes of Earth Observation (EO) data, together with post September 11/2001 security issues, have provided an impetus for new (automated and semi-automated) tools to analyze/mine such voluminous data.
- An ever-growing sophistication of user needs and expectations regarding GI products.
- Recognition of limitations with pixel-based image approaches (i.e., that current remote sensing image analysis largely neglects the spatial photointerpretive elements (i.e., texture, context, shape, etc), and that increased variability implicit within high-spatial resolution imagery confuses traditional pixel-based classifiers resulting in lower classification accuracies).
- Increasingly affordable, available and powerful computing tools.
- Increasing awareness that object-based methods can make better use of neglected spatial information implicit within RS images, and provide greater integration with vector based GIS.
- Recognition of the need for multiscale approaches in the monitoring, modeling and management of our environment, for which object-based methods are especially suited.
- Recognition that object-based approaches, represent viable solutions to mitigate the *modifiable areal unit problem* (MAUP, Openshaw, 1984), since they focus analysis on meaningful geographical objects rather than arbitrary defined spatial units i.e., individual pixels.
- GEOBIA concepts and tools also have the potential to be used in the operationalization of existing ecological theories (Burnett and Blaschke, 2003) such as the *Hierarchical Patch Dynamics Paradigm* (HPDP, Wu, 1999), which provides a conceptual framework for guiding and explaining the hierarchical/multiscale structure of landscapes.

6 GEOBIA SWOT

In this section we undertake a SWOT analysis to provide insight into the current state of GEOBIA, and to outline potential strategies to achieve the stated key objective (see *Section 4*). A SWOT Analysis is (one of many possible strategic planning tools) used to evaluate the *Strengths*, *Weakness*, *Opportunities* and *Threats* involved in a project, or any other situation requiring a decision. Our objective here is to apply this method of planning early in the discipline-life cycle of GEOBIA, so that concepts described

here can be used to strengthen and guide this emerging paradigm. In practice, once an objective has been established, a multidisciplinary team representing a broad range of experiences and perspectives should carry out a SWOT analysis; which is typically presented in the form of a matrix (see-Table. 1). Thus, we invite interested individuals to share their comments by participating in the recently developed GEOBIA *Wiki*[16], so as to further facilitate this discussion.

S.W.O.T	Helpful to achieving the objective	Harmful to achieving the objective
Internal (attributes of the organisation)	**S**trengths	**W**eaknesses
External (attributes of the environment)	**O**pportunities	**T**hreats

Table 1. SWOT matrix

SWOT's are defined based on the following criteria:

- *Strengths* are *internal* attributes of the organization that are helpful to the achievement of the objective.
- *Weaknesses* are *internal* attributes of the organization that are harmful to the achievement of the objective.
- *Opportunities* are *external* conditions that are helpful to the achievement of the objective.
- *Threats* are *external* conditions that are harmful to the achievement of the objective.

[16] The GEOBIA wiki (http://wiki.ucalgary.ca/page/GEOBIA) was created on February 03, 2007, and has received over 2000 page views (since September, 30, 2007).

In theory, SWOTs are used as inputs to the creative generation of possible strategies, by asking and answering the following four questions numerous times:

- How can we Use each Strength?
- How can we Stop each Weakness?
- How can we Exploit each Opportunity?
- How can we Defend against each Threat?

To reap the full benefits of a SWOT analysis it is important to use this tool correctly. In particular, it is most beneficial to look at the strengths and weaknesses originating within (i.e., internal to) the discipline or organization. For example, what do we do better than anyone else, what/where could we improve, what are others likely to see as weakness? Conversely, opportunities and threats should be externally focused i.e., what trends could you take advantage of, how can you turn your strengths into opportunities, what trends could do you harm? (MindTools, 2006).

The following sections represent a number of SWOTs identified as we considered the past, present and future of GEOBIA. They are by no means the only possible items, and in several cases – depending on one's perspective – individual items could exist in more than one category.

6.1 GEOBIA Strengths

- Partitioning an image into objects is akin to the way humans conceptually organize the landscape to comprehend it.
- Using image-objects as basic units reduces computational classifier loads by orders of magnitude, and at the same time enables the user to take advantage of more complex techniques.
- Image-objects exhibit useful features (e.g., shape, texture, contextual relations with other objects) that single pixels lack.
- Image-objects are less sensitive to MAUP than units that do not keep a correspondence with the structure of the phenomenon under study.
- Image-objects can be more readily integrated into a vector GIS than pixel-wise classified raster maps.
- The number of both free and commercially available GEOBIA software is increasing steadily (see Neubert et al., – this book).

6.2 GEOBIA Weaknesses

- Under the guise of 'flexibility' some commercial object-based software provides overly complicated options, resulting in time-consuming analyst 'tweaking'.
- There are numerous challenges involved in processing very large datasets. Even if GEOBIA is more efficient than pixel-based approaches, segmenting a multispectral image of hundreds or thousands of mega-pixels is a formidable task, thus efficient tiling/multiprocessing solutions are necessary.
- Segmentation is an *ill-posed problem*, in the sense that it has no unique solution, e.g., (i) changing the bit depth of your heterogeneity measure can lead to different segmentations. (ii) Even human photo-interpreters will not delineate exactly the same things.
- There is a lack of consensus and research on the conceptual foundations of this new paradigm, i.e., on the relationship between image-objects (segments) and landscape-objects (patches). For example, (i) what is the basis to believe that segmentation-derived objects are fine representations of landscape structural-functional units? (ii) How do you know when your segmentation is good? (iii) Is there a formally stated and accepted conceptual foundation?
- There exists a poor understanding of scale and hierarchical relations among objects derived at different resolutions. Do segments at coarse resolutions really 'emerge' or 'evolve' from the ones at finer resolutions? Should boundaries perfectly overlap (coincide) through scale? Operationally it's very appealing, but what is (if any) the ecological basis for this, and is such a basis necessary?

6.3 GEOBIA Opportunities

- *Object-Oriented* (OO) concepts and methods have been successfully applied to many different problem domains, not only computer languages, and they can be beneficially adapted to GEOBIA. This integration not only includes OO programming, but all the corpus of methods and techniques customarily used in biomedical imaging and computer vision (among others) that remain unknown to most of the remote sensing community.
- There are new information technology tools (e.g., Wikis) that may accelerate consensus and cohesion of a GEOBIA community.
- There is a steadily growing community of RS/GIS practitioners that currently use image segmentation for different GI applications. Thus,

as GEOBIA matures, new commercial/research opportunities will emerge to tailor object-based solutions for specific user needs i.e., forestry, habitat and urban mapping, mineral exploration, transportation, security, etc.

- Symmetric multiprocessing, parallel processing and grid computing are recent technologies that GEOBIA methods may build upon to tackle problems related to the analysis of large datasets.
- Adopting existing open GIS programming standards like Open Source GIS[17], and guidelines and methods from the Open Geospatial Consortium[18] along with provisioning to include Semantic Web[19] standards within current and new GEOBIA tools, will allow for re-use and integration between different platforms and data types, and opportunities for a web-wide dissemination and evaluation of image-object semantics. This in return will provide value-added opportunities for the sharing and generation of new GI, and the ability to build on expertise from different user communities throughout the globe.

6.4 GEOBIA Threats

- The visual appeal of image-objects, their easy GIS-integration and their enhanced classification possibilities and information potential have attracted the attention of major RS image processing vendors, who are increasingly incorporating new segmentation tools into their packages. This provides a wider choice for practitioners, but promotes confusion (among different packages, options, syntax, etc) and makes it more difficult to develop a cohesive GEOBIA community. Will a lack of protocols, formats, and standards lead to a segmentation of the field rather than a consolidation? Castilla and Hay (this book) refer to this critical GEOBIA threat as *The Tower of Babel problem* - where every user group develops different terminology than every other group for the same meaning, or the same term with different meanings

[17] http://opensourcegis.org/

[18] http://www.opengeospatial.org/

[19] At its core, Tim Berners-Lee's Semantic Web comprises a philosophy, a set of design principles, collaborative working groups, and a variety of enabling technologies. Some elements of the semantic web are expressed as prospective future possibilities that have yet to be implemented or realized. (http://en.wikipedia.org/wiki/Semantic_Web)

resulting in confusion, isolation, a fighting over standards, and a negative or flat progression of the discipline[20].
- Trying to make distinct GEOBIA from other OO concepts and methods (e.g., by using terms such as 'object-based' instead of 'object-oriented') may contribute to insulation (of users in an esoteric world of 'objects') and isolation (of the concept) rather than to consolidation.
- GEOBIA is far from being an established paradigm, yet many users of commercial segmentation software do not recognize this fundamental fact. GEOBIA is not one specific research or commercial software. Much still remains to be solved and discovered.

7 GEOBIA Tenets

Based on these SWOT items, we offer the following GEOBIA tenets as fundamental components of what we currently see this discipline as, and as guides to what it could become.

GEOBIA is…

- *Earth centric* – its data sources originate from the surface of this planet.
- *Multi-source capable* – its methods provide for the inclusion of multiple different digital data types/sources within a common geographic referent and for the flow of information and intelligence from pixel-based RS data to GIS ready polygons.
- *Object-based* – meaningful image-object delineation is a prerequisite of this approach, from which relevant intelligence can be generated.
- *Multiscale* – a scene is often composed of objects of different size, shape and spatial location, thus multiscale analysis both within a hierarchical level and between levels is essential. Because GEOBIA is multiscale, potential exists to model alternative 'multiscale' realities based on selective user defined aggregations of fine scale segments and or their attributes.
- *Contextual* – it has the ability to *incorporate* or *integrate* 'surrounding' information and attributes. When processing RS data, this in-

[20] Tim Berners-Lee's development of the Semantic web represents a significant effort to resolve this kind of issue at a global level, but at a local level, semantic and ontological standards need to be developed, shared, and agreed upon within specific application domains, and tied to semantic web formats.

cludes mechanisms to quantify an object's photointerpretive elements i.e., colour (hyperspectral), tone, size, shape, pattern, location, and texture. By adding time (multitemporal imagery), as well as other attributes such as height (Lidar) and heat (Thermal) into the 'contextual pool', there will be a greater information potential for each image-object than ever possible for individual pixels.

- *Adaptive* – it allows for the inclusion of human semantics and hierarchical networks – whether through experts systems, or expert interpreters, so that analysis may be tailored to specific user needs. However, to be fully adaptive, GEOBIA tools need to build on existing Open GIS standards and provide mechanisms to integrate user and domain specific ontologies into a semantic web so as to globally facilitate improved sharing, integration and generation of new synergistic GI and the development of their associated markets. For example, given a multispectral image, one user may derive a general Landuse classification. This information may then be shared/sold across the web to another who builds upon this information to single-out patches of Amazon Acai palm trees for lumber and thatching materials. This new GI layer may then be shared or sold to another user in a different part of the world, and when combined with their expertise and knowledge could provide opportunities to harvest Acai berries and explore them as a ground-breaking leukemia cure (based on a true scenario). In this case, one initial dataset, combined with a sharing of semantic information results in myriad different GI products and markets.

8. Conclusion

GEOBIA is a sub-discipline of GIScience devoted to developing automated methods to partition remote sensing imagery (of our planets surface) into meaningful image-objects, and assessing their characteristics through scale. Its primary objective is the generation of geographic information (in GIS-ready format) from which new intelligence can be obtained.

In this paper we have formally defined *Geographic Object-Based Image Analysis* (GEOBIA); provided a justification for this new name; outlined a key objective of this new discipline; identified a number of Strengths, Weakness, Opportunities and Threats (SWOT) that GEOBIA faces; and proposed a number of GEOBIA tenets. It is important to note that a key issue faced by this new discipline is to ensure that an integrative, well understood, and easily defined ontology is developed and incorporated within

the research and commercial software that is currently being built and used. A way to construct and promulgate such ontology is by creating a living document – a GEOBIA guide book - to which practitioners can contribute and turn to for understanding and direction. This could further be facilitated by adopting established Open GIS standards and semantic web protocols, so that geoinformation could be shared and integrated more easily. While this tome on OBIA represents a positive beginning, we propose that the existing GEOBIA *Wiki* – with its world wide accessibility - is an ideal vehicle to develop such a guide, and cordially invite all interested parties to participate in building a stronger GEOBIA community of practice.

Acknowledgements

This research has been generously supported in grants to Dr Hay from the University of Calgary, the Alberta Ingenuity Fund, and the Natural Sciences and Engineering Research Council (NSERC). The opinions expressed here are those of the authors, and do not necessarily reflect the views of their funding agencies. We thank Mr. Ivan Lizarazo for his initial input upon which the GEOBIA Tenets were subsequently developed.

References

Blaschke T, Lang S (2006) Object-Based Image Analysis for Automated Information Extraction – A Synthesis. Proceedings of MAPPS/ASPRS. November 6-10. San Antonio, Texas

Burnett C, Blaschke T (2003) A multi-scale segmentation/object relationship modelling methodology for landscape analysis. Ecological Modelling 168(3): 233-249

Castilla G, Hay GJ (2007) Image-objects and geographic-objects. In: Blaschke T, Lang S, Hay GJ (Eds) Object-Based Image Analysis - Spatial concepts for knowledge-driven remote sensing applications. Springer-Verlag, Berlin

Definiens (2007) Definiens Bridges the Gap between Remote Sensing and GIS. Press release, Munich, Germany/San Diego, CA, USA – June 18th. URL: http://www.definiens.com/news_dtls.php?id=117&link_id=27&sublink_id=30&PHPSESSID=82f5213ef3acbfd320224e4a90900dcc

Hay GJ, Castilla G (2006) Object-Based Image Analysis: Strengths, Weaknesses, Opportunities and Threats (SWOT). International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. No. XXXVI-4/C42

Hitchings S (2003) Policy assessment of the impacts of remote-sensing technology. Space Policy 19:119-125

Kuhn TS (1962) The Structure of Scientific Revolutions. The Chicago University Press, Chicago

Lang S, Blaschke T (2006) Bridging remote sensing and GIS – what are the main supporting pillars? International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences vol. XXXVI-4/C42

MindTools (2006) SWOT Analysis. URL: http://www.mindtools.com/pages/article/newTMC_05.htm

Neubert M, Herold H, Meinel G (2007) Evaluation of remote sensing image segmentation quality. In: Blaschke T, Lang S, Hay GJ (Eds) Object-Based Image Analysis - Spatial concepts for knowledge-driven remote sensing applications. Springer-Verlag, Berlin

Openshaw S (1984) The Modifiable Areal Unit Problem. *Concepts and Techniques in Modern Geography* (CATMOG), vol. 38,. GeoBooks, Norwich, pp. 40

Roush, W (2007) Second Earth. Technology Review July/August Issue. MIT Press.URL: http://www.technologyreview.com/printer_friendly_article.aspx?id=18888

Schiewe J, Tufte L, Ehlers M (2001) Potential and problems of multi-scale segmentation methods in remote sensing. Geographische Informationssysteme 6: 34-39

Wikipedia (2007) Wiki. URL: http://en.wikipedia.org/wiki/Wiki

Wu J (1999) Hierarchy and scaling: extrapolating information along a scaling ladder. Can J Remote Sensing 25(4): 367-380